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J Anim Sci 2003. 81:1837-1846.

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Influence of milk production potential on forage dry matter intake by multiparous and primiparous Brangus females[1,2]

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ABSTRACT: Brangus cows (n = 29) were used in three experiments to evaluate the effects of parity (multiparous vs. primiparous) and potential genetic merit for milk production (high vs. low) on forage intake during late gestation, early lactation, and late lactation. Cows were selected for milk production based on their sire's EPD for milk production (MEPD). Cows had ad libitum access to (130% of previous 2-d average intake) low-quality hay (5.3% CP and 76% NDF), and cottonseed meal was supplemented to ensure adequate degradable intake protein. All females were adapted to diets for at least 7 d, and individual intake data were collected for 9 d. During the lactation trials, actual milk production was determined using a portable milking machine following a 12-h separation from calves. During late gestation, multiparous cows consumed 24% more (P = 0.01) forage DM (kg/d) than primiparous cows; however, parity class did not influence forage intake when intake was expressed relative to BW. Furthermore, MEPD did not influence forage intake during late gestation. During early lactation, multiparous cows produced 66% more (P < 0.001) milk than primiparous cows, and high MEPD tended (P = 0.10) to produce more milk than low MEPD. Multiparous cows consumed 19% more (P < 0.0001) forage DM than did primiparous cows when expressed on an absolute basis, but not when expressed on a BW basis. High-MEPD cows consumed 8% more (P < 0.05) forage DM than did low-MEPD cows. During late lactation, multiparous cows produced 84% more milk than primiparous cows, although MEPD did not influence (P = 0.40) milk yield. In addition, multiparous cows consumed 17% more (P < 0.01) forage DM per day than primiparous cows, but when intake was expressed relative to BW, neither parity nor MEPD influenced forage DMI during late lactation. Milk yield and BW explained significant proportions of the variation in forage DMI during early and late lactation. Each kilogram increase in milk yield was associated with a 0.33- and 0.37-kg increase in forage DMI for early and late lactation, respectively. Results suggest that multi- and primiparous cows consume similar amounts of low-quality forage DM, expressed per unit of BW, during late gestation and lactation. Selecting beef cows for increased genetic merit for milk production increases forage DMI during early lactation.

Key Words: Beef Cows, Intake, Milk Production, Parity

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Introduction

In order for cow-calf producers to optimize efficiency in their production systems, it is imperative for cows to calve at 12-mo intervals. The primiparous beef cow presents challenges to achieving this goal since they typically have longer postpartum intervals (Bellows and Short, 1978; Triplett et al., 1995) and lower pregnancy rates upon rebreeding (Rae et al., 1993) compared with multiparous cows. Reduced reproductive performance in cows and heifers can result from inadequate nutrient intake pre- or postpartum (Randel, 1990). Varel and Kreikemeier (1999) reported that mature cows consumed more forage than 10-mo-old heifers when expressed per unit of metabolic BW, but not per unit of BW. This difference was attributed to increased forage utilization by the mature cows. However, data comparing forage intake of primiparous and multiparous females during gestation and lactation are limited.

[1]Approved for publication by the director of the Oklahoma Agric. Exp. Stn.

[2]The authors thank S. Schmidt and the undergraduates of Redlands Community College for their assistance in the daily management of the cattle.

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Received July 19, 2002.

Accepted March 21, 2003.

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Table 1. Chemical composition of bermudagrass hay and cottonseed meal for all experiments (percentage of DM unless specified)

Item	Hay	Cottonseed meal
OM	87.9	85.1
CP	5.3	44.6
Degradable intake protein, % of CP	45.0	57.0[a]
NDF, ash-free	75.9	33.3
ADF, ash-free	47.9	24.9
Acid detergent insoluble ash	3.7	0.5
Lignin	6.4	—
Neutral detergent insoluble CP	2.0	—
Acid detergent insoluble CP	0.9	—
Crude fat	2.0	3.2[a]
TDN	52	75[a]

[a]Tabular values (NRC, 1996).

Selection for increased milk production based on sire EPD results in increased milk production (Diaz et al., 1992; Marston et al., 1992; Mallinckrodt et al., 1993). However, this increase may be at the cost of body nutrient reserves (Minick et al., 2001). Lactating cows consume more forage DM than gestating cows (Vanzant et al., 1991; Stanley et al., 1993; Marston and Lusby, 1995). Furthermore, as milk yield increases, so does forage DMI (Wyatt et al., 1977; Wagner et al., 1986; Hatfield et al., 1989). However, these researchers used various breed crosses of different biological types to establish different levels of milk production. The relationship between the predicted differences in milk yield, stage of production, and forage DMI has not been established. Therefore, our objective was to evaluate the influence of cow parity and predicted difference in milk production on forage DMI in late gestation, early lactation, and late lactation.

Materials and Methods

Three experiments were conducted at the USDA-ARS Grazinglands Research Laboratory in El Reno, OK, to evaluate the effects of parity and predicted genetic merit for milk production on forage DMI in Brangus cows. All experiments followed the animal use guidelines as stated by FASS (1999). All three experiments used the same low-quality hay (Table 1). The hay was harvested at the USDA-ARS Grazinglands Research Laboratory during the summer of 1998 from a bermudagrass–native prairie pasture and was stored outside as round bales until feeding. Round bales were rebaled into small square bales to facilitate feeding the animals individually. During rebaling, the outer layer (15 cm) that appeared damaged was separated and discarded.

Selection Population

Cows used in the following series of experiments were selected from a population comprising 65 multiparous and 39 primiparous purebred Brangus cows. The breeding season was initiated 30 d earlier for primiparous cows vs. multiparous cows in anticipation of extended postpartum intervals in the primiparous cows. Within each parity class (multiparous vs. primiparous), cows were ranked based on sire EPD for milk production (**MEPD**). Within the multiparous cow population, 43 sires were represented with a range of sire MEPD of +6.6 to −11.4. The primiparous cow population had 17 sires represented with a range of sire MEPD of +8.2 to −6.5. Before Exp. 1, cows (n = 24) were selected from the upper and lower 25% of represented sires for each parity population. Before Exp. 2 and 3, replacements were selected if cows failed to calve or lost their calf. Selected replacements had a sire MEPD similar to that of the cow being replaced.

Experiment 1—Late Gestation

In December 2000, 12 multiparous and 12 primiparous cows were selected as previously described for high- and low-sire MEPD before the initiation of Exp. 1. Multiparous cows averaged 61 d and primiparous cows averaged 33 d prepartum. One cow was removed during Exp. 1 due to lameness, and data from three primiparous cows was excluded because of early calving. Cows were weighed at the beginning and end of the feeding period. Average weight for the feeding period was used to express intake relative to unshrunk BW and $BW^{0.75}$. Body condition scores (scale of 1 to 9; Wagner et al., 1988) were determined by two independent evaluators at the beginning of each feeding period and average scores are reported.

Before initiating Exp. 1, a sample of the forage was analyzed for chemical composition. Animal and forage characteristics were used to estimate metabolizable protein (**MP**) balance, degradable intake protein (**DIP**) balance, and the amount of supplementation necessary to ensure an adequate supply of each. Forage grab samples were collected from six round bales before rebaling. Samples were dried (55°C) in a forced-air oven, ground to pass a 1-mm screen, and composited on an equal-weight basis. Degradable intake protein was determined by incubating the forage sample with the enzyme *Streptomyces griseus* and measuring nitrogen disappearance (Roe et al., 1990). The 1996 Beef NRC Model, Level One, was used to estimate protein balance, assuming a microbial efficiency of 11% (Russell et al., 1992). Cottonseed meal (**CSM**; Table 1) was supplemented so that all parity classes in each experiment had a calculated positive DIP balance of at least 150 g/d and a positive MP balance. Based on these calculations, the daily amount of CSM supplemented was determined using each cow's initial BW and fed at the rate of 0.18 kg of DM/100 kg of BW for multiparous cows and 0.27 kg/100 kg of BW for primiparous cows (Table 2).

Cows were housed in a partially enclosed barn (18 × 73 m) equipped with pens measuring 4.6 × 4.6 m. Two cows of similar weight and parity, representing high

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Table 2. Sire milk EPD, age, weight, body condition score, and days relative to parturition of Brangus cows used in Exp. 1, 2, and 3, respectively[a]

Variable	High sire MEPD[b] Multiparous	High sire MEPD[b] Primiparous	Low sire MEPD Multiparous	Low sire MEPD Primiparous
Late gestation (Exp. 1)				
Number of cows	6	5	5	4
Sire milk EPD[c]	+4.3 (0.85)	+5.0 (1.89)	−6.1 (3.47)	−5.0 (2.05)
Age, mo	46 (1.1)	23 (1.9)	61 (27.4)	22 (0.6)
Unshrunk BW, kg	578 (58.1)	502 (26.9)	599 (59.8)	468 (31.7)
BCS[d]	4.4 (0.50)	4.8 (0.26)	4.9 (0.29)	4.8 (0.29)
Days prepartum	56 (11.0)	36 (24.3)	57 (12.0)	40 (21.4)
Early lactation (Exp. 2)				
Number of cows	6	6	6	6
Sire milk EPD[c]	+4.3 (0.85)	+4.7 (1.87)	−5.7 (1.65)	−5.7 (3.32)
Age, mo	50 (1.1)	27 (2.2)	65 (27.2)	26 (0.7)
Unshrunk BW, kg	549 (48.0)	459 (25.3)	557 (37.1)	434 (23.2)
BCS[c]	4.3 (0.52)	4.1 (0.38)	4.6 (0.38)	4.2 (0.61)
Days postpartum	48 (10.1)	74 (18.6)	46 (6.3)	79 (13.0)
Late lactation (Exp. 3)				
Number of cows	6	6	6	6
Sire milk EPD[c]	+4.3 (0.85)	+4.7 (1.87)	−5.7 (1.65)	−5.7 (3.32)
Age, mo	53 (1.1)	30 (2.2)	68 (27.2)	29 (1.1)
Unshrunk BW, kg	540 (51.7)	467 (31.7)	559 (51.2)	454 (32.7)
BCS[d]	4.3 (0.63)	4.3 (0.33)	4.5 (0.32)	4.2 (0.41)
Days postpartum	154 (10.1)	188 (18.6)	152 (6.3)	181 (13.5)

[a]Except for number of cows, values in table are the mean ± SD.
[b]MEPD = predicted genetic merit for milk production.
[c]Milk EPD is expressed as kilograms of weaning weight in offspring due to maternal milk.
[d]Body condition score, scale 1 to 9.

and low sire MEPD were allotted to a pen. Cows were individually fed hay and supplement daily by using the Calan gate system (American Calan Inc., Northwood, NH) and were trained to the gates and adapted to the diet simultaneously. The training and adaptation period was 24 d followed by a 9-d collection period. All animals had ad libitum access to water and a trace mineralized salt block (contained not less than 93% NaCl, 3,500 ppm of Zn, 2, 800 ppm of Mn, 1, 750 ppm of Fe, 350 ppm of Cu, 70 ppm of I, and 70 ppm of Co). Cows had ad libitum (130% of the previous 2-d average) access to forage. During the intake collection period, hay, CSM, and orts were subsampled daily. Hay and CSM were composited for the period, and orts were composited by individual cow. Fecal grab samples were collected each day before feeding and composited for the period by individual cow.

Experiment 2—Early Lactation

In March 2001, 12 multiparous cows and 12 primiparous cows were assigned to one of two feeding periods such that each period was balanced for parity and sire MEPD. Average day postpartum at the initiation of Period 1 was 63 d, with a range of 53 d. Average day postpartum at the initiation of Period 2 was 60 d with a range of 52 d. Multiparous cows averaged 47 d and primiparous cows averaged 76 d postpartum.

All cows were placed in a drylot for a 7-d adaptation to the diet (before measuring milk production). Following the 7-d drylot adaptation, milk production was estimated using a single-cow portable milking machine (Brown et al., 1996). Cows and calves were separated at 1900 on the evening before milking. Hay and water were provided during the 12-h separation. Milking began at 0700 the next morning. Approximately 10 min before milking, cows were sedated with 1.5 mL of acepromazine maleate (10 mg/mL, i.m.; Phoenix Pharmaceutical, Inc., St. Joseph, MO) and 1.0 mL of oxytocin (20 USP units/mL, i.m.; Phoenix Pharmaceutical, Inc.) was administered to induce milk release. All pharmaceuticals were administered under the direct supervision of the staff veterinarian. Daily milk yield was estimated as the net weight of milk adjusted to a 24-h basis (Brown et al., 1996).

Immediately following milk production estimation, cows were moved to the same facilities described in Exp. 1. Each pen housed a single cow-calf pair. Cow-calf pairs were randomly allotted to pens. Each cow-calf pair was then individually fed for an additional 7-d adaptation period and 9-d data collection period. Cows had ad libitum access to forage and CSM was fed at the rate of 0.36 kg of DM/100 kg of BW and 0.45 kg of DM/100 kg of BW for multi- and primiparous cows, respectively. Forage, CSM, orts, and fecal samples were collected as previously described. Calves were assumed to consume minimal forage; however, data are reported as cow-calf pair intakes since the calf was not separated.

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Experiment 3—Late Lactation

In July 2001, 12 multiparous cows and 12 primiparous cows were assigned to two feeding periods such that each period was balanced for parity and sire MEPD. In Period 1, the average days postpartum was 162 d, with a range of 53 d, and in Period 2, the average days postpartum was 178 d, with a range of 52 d. Multiparous cows averaged 149 d and primiparous cows averaged 178 d postpartum. Similar to Exp. 2, all cows were placed in a drylot for 7 d before measuring milk production, and then each cow-calf pair was randomly allotted to a pen for an additional 7-d adaptation period followed by the 9-d collection period. The barn in this experiment had enclosed sides and measured 15 × 73 m and each pen measured 3.7 × 3.7 m. Milk production was determined as previously described. Because of the expected increase in calf forage intake, the feeding regime differed from the previous two experiments. All pairs were separated and cows were offered hay for two 4-h feeding bouts at 0730 and 1800, similar to the experiment of Ovenell et al. (1991). Cows had ad libitum access to forage, as described previously. Cottonseed meal feeding levels were determined as described in Exp. 1, resulting in CSM being fed at the rate of 0.36 kg of DM/100 kg of BW and 0.41 kg of DM/100 kg of BW for multi- and primiparous cows, respectively. While separated, calves were offered ad libitum access to water, hay, and a 14% CP creep feed. Daily intake data are reported as the sum of two 4-h feeding bouts.

Forage, Feces, and Supplement Analysis

Forage, orts, and fecal samples were dried at 55°C in a forced-air oven and were ground to pass a 2-mm screen. Dry matter and ash determinations were conducted in accordance with approved methods of the AOAC (1996). Nitrogen content of forage, CSM, and feces was determined by combustion (Leco-NS2000, Leco Corp., St. Joseph, MO) in accordance with AOAC (1996). Sample concentrations of NDF and ADF were determined by methods described by Van Soest et al. (1991). Forage lignin concentration was determined by digesting ADF residue in 72% (wt/wt) sulfuric acid (AOAC, 1996). Degradable intake protein of the forage was estimated (Roe et al., 1990) by measuring nitrogen disappearance during a 48-h incubation in a borate–phosphate buffer containing protease type XIV from *Streptomyces griseus* (P-5147, Sigma Chemical Co., St. Louis, MO). Total digestible nutrient concentration of the forage was determined by the summative equation of Weiss et al. (1992). Tabular values for DIP, crude fat, and TDN for CSM were used in the calculations (NRC, 1996).

Fecal output of the cows was estimated using acid detergent insoluble ash as an internal marker. During each experiment, a single fecal sample was collected daily 1 h before feeding for 5 d and composited. Acid detergent insoluble ash in forage and feces was determined as the residue following complete combustion of the ADF residue (Van Soest et al., 1991). Total diet organic matter digestibility was calculated as described by Cochran and Galyean (1994).

Statistical Analysis

Data in Exp. 1 were analyzed as a split plot arrangement using least squares ANOVA (PROC MIXED; SAS Inst., Inc., Cary, NC). The main effects of parity (multiparous vs. primiparous) and sire MEPD (high vs. low) and the interaction were included in the model as fixed effects. Pen was included in the model as a random effect and was nested within parity and within the parity × MEPD interaction to test the main effects and interaction, respectively. Data in Exp. 2 and 3 were analyzed as a 2 × 2 factorial arrangement using least squares ANOVA (PROC MIXED; SAS Inst. Inc.). Period was treated as a random effect, and the fixed effects of parity, MEPD, and the interaction were included in the model. Due to the known difference in days relative to parturition for all experiments, we were concerned that the difference in average days among parity groups could influence milk yield and DMI. Therefore, days of parturition was initially included in the model as a covariate for all dependent variables and was again found to be uniformly nonsignificant ($P > 0.25$) for all experiments. As a result, days of parturition was not included in the final model for all traits measured. For the lactation trials (Exp. 2 and 3), simple linear and multiple regression models were developed (PROC REG; SAS Inst., Inc., Cary, NC) for the purpose of evaluating the relationship between animal factors and forage DMI. Forage DMI was regressed on parity class as well as the linear, quadratic and cubic terms for milk yield, BW, $BW^{0.75}$, and BCS. Parity class was expressed with numeric code where multiparous = 1 and primiparous = 0. The appropriateness of fit for each model was evaluated using the change in R^2 and Mallows's C_P statistic (MacNeil, 1983). Data from cows that were maintained through all three experiments were pooled and evaluated incorporating stage of production into the model. These data were analyzed using repeated measures analysis (PROC MIXED; SAS Inst. Inc.) and effects in the model included sire MEPD, stage of production, and the interaction. The covariance structure was modeled using the spatial power law structure because of the unequally spaced time points (stage of production) for these experiments.

Results and Discussion

Late Gestation

When forage DMI was expressed on an absolute basis (kg/d), multiparous cows consumed more forage than primiparous cows ($P = 0.01$; Table 3). Yet, when intake was expressed relative to BW (kg/100 kg of BW) or metabolic BW (kg/100 kg of $BW^{0.75}$; data not shown),

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Table 3. Least squares means for forage intake and digestibility by cows consuming low-quality hay during late gestation (Exp. 1)

	High sire MEPD[a]		Low sire MEPD			P[b]		
Variable	Multiparous	Primiparous	Multiparous	Primiparous	SEM	Parity	MEPD	X[c]
Supplement DMI, kg/d	1.03	1.34	1.08	1.25	—	—	—	—
Forage DMI, kg/d	10.1	8.1	10.3	8.4	0.70	0.01	0.73	0.88
Forage DMI, kg/100 kg of BW	1.76	1.59	1.71	1.73	0.13	0.51	0.73	0.43
Apparent diet OM digestibility, %	56.0	57.9	58.0	55.4	0.93	0.62	0.73	0.02
Total digestible OM intake (TDOMI), kg/d	5.5	4.8	5.8	4.7	0.32	0.02	0.75	0.51
TDOMI, kg/100 kg of BW	0.96	0.96	0.97	0.98	0.06	0.94	0.76	0.89

[a]MEPD = predicted genetic merit for milk production.
[b]P-value for differences due to effects in the model.
[c]X denotes the interaction of parity and MEPD.

neither parity nor sire MEPD affected forage DMI (Table 3).

Varel and Kreikemeier (1999) compared forage intake and utilization by mature cows and 10-mo-old heifers fed alfalfa and brome hay. Forage intake did not differ between cows and heifers when expressed per kilogram of BW; however, when expressed per unit of $BW^{0.75}$, mature cows consumed 27% more alfalfa and 50% more brome hay than the heifers. Additionally, these researchers observed that mature cows had faster rates of ruminal NDF digestion, which may have been attributed to a smaller ruminal fluid fill that turns over more rapidly. We did not observe a difference in intake when expressed per unit of $BW^{0.75}$. One explanation may be that the primiparous cows used in our study were older and closer to their expected mature weight compared to the 10-mo-old heifers used by Varel and Kreikemeier (1999).

Fiss and Wilton (1992) evaluated various breeding systems from 1980 to 1988, including straightbred Herefords and crossbred systems involving Angus, Gelbvieh, Pinzgauer, Tarentaise, Charolais, Simmental, and Maine Anjou. Cows were fed a 50% corn silage and 50% haylage diet (DM basis). The crossbred cows produced 88% more milk during lactation than the straightbred Hereford cows, indicative of increased genetic potential for milk production. These authors reported total energy intake for gestation, which was considered the time from weaning through parturition. The crossbred cows consumed 22% more feed energy (Mcal of ME/d) during gestation. Their increase in feed intake during gestation may have been a function of BW since the crossbreds also were heavier at weaning compared with the straightbred Herefords. In our study, divergent selection for milk production did not influence forage intake of Brangus multi- and primiparous cows during late gestation.

Lactation

Milk Production. Cows selected for high and low sire MEPD tended to differ in milk yield during early lactation from those selected for high sire MEPD, producing 4.4 kg more milk than those selected for low sire MEPD ($P = 0.10$; Table 4). This difference was not observed ($P = 0.4$) during late lactation (Table 5). Our data concur with previous research that indicates selection for sire milk EPD successfully predicts differences in milk yield of the daughters (Diaz et al., 1992; Marston et al., 1992; Mallinckrodt et al., 1993). Additionally, cows that produce more milk tend to have faster declines in yield after achieving peak milk production (Mallinckrodt et al., 1993; Minick et al., 2001).

When expressed as milk yield per day, primiparous cows produced 40 and 46% less milk than multiparous cows during early ($P < 0.001$; Table 4) and late lactation ($P < 0.001$; Table 5), respectively. Hansen et al. (1982) evaluated the effects of parity and milk production on postpartum reproductive performance in beef cows. Cows in their third lactation produced about 30% more than the same cows had during their first lactation. Clutter and Nielsen (1987) evaluated the mean 205-d milk production for dams of various ages. They reported that milk production was 25% higher in mature cows (4 to 5 yr old) compared with primiparous cows. However, our data concur with the model proposed by Fox et al. (1988) in that primiparous cow milk production is adjusted to 60% of mature milk production. The NRC (1996) model uses a 26% reduction in milk yield for primiparous 2-yr-old cows vs. mature cows. It is possible that the relatively low forage quality used in this experiment, and the resulting low energy intake, limited milk production of primiparous cows more than multiparous cows.

Forage Intake. Expressing forage DMI relative to $BW^{0.75}$ (data not shown) yielded similar results compared with expressing forage DMI relative to BW. Therefore, forage DMI data is presented (Tables 4 and 5) and discussed in terms of kg of DM/100 kg of BW. During early lactation, cows from sires with high MEPD consumed more forage daily ($P = .01$; Table 4) and more forage per 100 kg of BW ($P < 0.03$; Table 4) than those from sires with low MEPD. However, during late lactation (Table 5), MEPD class did not influence intake expressed on an absolute ($P = 0.23$) or BW basis ($P = 0.17$). Hatfield et al. (1989) evaluated the relationship

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Table 4. Least squares means for forage intake and digestibility by cows consuming low-quality hay during early lactation (Exp. 2)

	High sire MEPD[a]		Low sire MEPD			P[b]		
Variable	Multiparous	Primiparous	Multiparous	Primiparous	SEM	Parity	MEPD	X[c]
Milk yield, kg/d	11.3	7.8	10.5	5.3	2.13	<0.001	0.10	0.39
Milk yield, kg/100 kg of BW	4.6	3.8	4.1	2.7	0.45	0.02	0.09	0.46
Supplement DMI, kg/d	1.95	2.01	1.98	1.94	—	—	—	—
Forage DMI, kg/d	13.8	12.0	13.2	10.6	0.36	<0.001	0.01	0.29
Forage DMI, kg/100 kg of BW	2.53	2.63	2.36	2.45	0.07	0.20	0.03	0.90
Apparent diet OM digestibility, %	51.5	55.8	53.1	54.7	1.37	0.05	0.86	0.33
Total digestible OM intake (TDOMI), kg/d	7.2	7.0	7.1	6.1	0.24	0.02	0.06	0.12
TDOMI, kg/100 kg of BW	1.31	1.52	1.28	1.40	0.05	<0.01	0.11	0.35
Mcal of NE_m in milk/Mcal of NE_m available for production[d]	1.74	1.12	1.79	0.94	0.19	0.001	0.75	0.56

[a]MEPD = predicted genetic merit for milk production.
[b]*P*-value for differences due to effects in the model.
[c]X denotes the interaction of parity and MEPD.
[d]Mcal of NE_m used for milk was estimated using average milk energy concentration (0.72 Mcal of NE_m/kg of milk) in beef cows from NRC, 1996. Mcal of NE_m available for production was estimated by subtracting maintenance requirements (NRC, 1996) from daily NE_m intake. Daily NE_m intake was estimated from DMI and apparent digestibility data.

between milk production potential and forage intake during early and late lactation. The cows used in their experiment were F_1 crosses produced from Hereford, Red Poll, and Milking Shorthorn sires with Angus dams. These breed crosses were designed to create differences in milk production potential while maintaining similar growth and mature size. These authors observed a quadratic increase in intake expressed per unit of BW as milk production levels increased during both early and late lactation. Furthermore, Wagner et al. (1986) used cows with an increasing percentage of Simmental, but similar BW, to generate a range in milk production and measured forage intake using an external marker. As the proportion of Simmental increased in the cows, so did milk production and forage intake expressed as a percentage of BW. From these experiments and the results of our study, a positive relationship between forage DMI and milk production is apparent.

Multiparous cows consumed 19% more forage DM than primiparous cows on an absolute basis during early lactation ($P < 0.001$; Table 4) and late lactation ($P < 0.01$; Table 5). However, when expressed per unit of BW or $BW^{0.75}$ (data not shown), both groups consumed similar amounts of forage. During both stages of lactation, primiparous cows had approximately 5% higher OMD than multiparous cows ($P < 0.01$ and $P = 0.05$ for early and late lactation, respectively). However, the observed increase in OMD did not offset the lower forage intake of primiparous cows compared with the mul-

Table 5. Least squares means for forage intake and digestibility by cows consuming low-quality hay during late lactation (Exp. 3)

	High sire MEPD[a]		Low sire MEPD			P[b]		
Variable	Multiparous	Primiparous	Multiparous	Primiparous	SEM	Parity	MEPD	X[c]
Milk yield, kg/d	8.7	5.4	8.8	4.1	0.94	<0.001	0.40	0.34
Milk yield, kg/100 kg of BW	3.59	2.52	3.49	2.02	0.39	<0.001	0.36	0.55
Supplement DMI, kg/d	1.93	1.87	2.00	1.83	—	—	—	—
Forage DMI, kg/d	11.7	10.8	12.0	9.4	0.47	<0.01	0.23	0.09
Forage DMI, kg/100 kg of BW	2.18	2.32	2.14	2.08	0.09	0.69	0.17	0.30
Apparent diet OM digestibility, %	56.3	58.4	55.8	60.8	2.45	<0.01	0.38	0.19
Total digestible OM intake (TDOMI), kg/d	6.8	6.6	6.9	6.1	0.34	0.08	0.47	0.32
TDOMI, kg/100 kg of BW	1.27	1.41	1.24	1.34	0.07	0.02	0.37	0.71
Mcal of NE_m used for milk/Mcal of NE_m available for production[d]	1.68	0.97	1.87	1.02	0.22	<0.001	0.51	0.71

[a]MEPD = predicted genetic merit for milk production.
[b]*P*-value for differences due to effects in the model.
[c]X denotes the interaction of parity and MEPD.
[d]Mcal of NE_m used for milk was estimated using average milk energy concentration (0.72 Mcal of NE_m/kg of milk) in beef cows from NRC, 1996. Mcal of NE_m available for production was estimated by subtracting maintenance requirements (NRC, 1996) from daily NE_m intake. Daily NE_m intake was estimated from DMI and apparent digestibility data.

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Table 6. Sources of variation for forage dry matter intake (kg/d) by Brangus cows during early lactation

Intercept	Milk[a]	Milk[a]	BW[b]	BCS[c]	Parity[d]	R^2	C_p
Single variable							
9.554*	0.3273*	—	—	—	—	0.52	28.11
8.160	0.7155	−0.0048	—	—	—	0.55	8.60
2.864	—	—	0.0191*	—	—	0.68	12.40
8.023*	—	—	—	1.023*	—	0.11	69.0
11.53*	—	—	—	—	2.161*	0.55	25.1
Two variable							
0.821	0.7769*	−0.0392*	0.0164*	—	—	0.82	2.02
5.259	0.8030*	−0.0062	—	0.6336	—	0.59	25.26
8.352*	0.679*	−0.0063*	—	—	1.498	0.69	14.90
3.296*	—	—	0.0197*	−0.170	—	0.68	14.16
4.164*	—	—	0.0161*	—	0.4507	0.68	13.73
10.246*	—	—	—	0.2633	2.073*	0.56	26.43
Three variable							
4.179*	0.1421*	—	0.0139*	—	0.0582	0.73	10.59
4.476*	—	—	0.0167*	−0.1461	0.4299	0.69	15.55
9.297*	0.1812*	—	—	0.2051	1.306*	0.64	19.80
0.6564	0.7836*	−0.0396*	0.0162*	0.0529	—	0.82	4.00
0.8163	0.7770*	−0.0081*	0.0164*		−0.0016	0.82	4.02
6.490*	0.7371*	−0.0070*	—	0.4043	1.400	0.71	15.45
4.4753*	0.1425*	—	0.0146*	−0.1389	0.0391	0.74	12.43
Four variable							
0.6696	0.7834*	−0.0082*	0.0162*	0.0532	0.0052	0.82	6.00

[a]Milk yield was expressed as kg/d and both linear and quadratic expressions were considered a single variable.
[b]Body weight, kg.
[c]Body condition score, scale 1 to 9.
[d]Parity class where multiparous = 1, and primiparous = 0.
*Significant in model at $P < 0.10$.

tiparous cows. As a result, multiparous cows consumed approximately 9% more digestible OM (Tables 4 and 5) than primiparous cows at both stages of lactation.

Neutral detergent fiber intake (data not shown) ranged from 1.9 to 2.2 kg of NDF/100 kg of BW during early lactation and 1.7 to 1.9 kg of NDF/100 kg of BW during late lactation. Mertens (1987) found NDF to be positively related to the fill effect of a diet and further determined that maximal intake in lactating dairy cows occurs when NDF intake is 1.2 kg/100 kg of BW. This relationship has been incorporated into the estimation of intake used in the determination of relative feed value (Linn et al., 1987). However, Moore and Undersander (2002) discuss the point that extrapolation of the data from high-concentrate mixed diets (Mertens, 1987) to predominantly forage systems may not be rational or justified. Our data support Moore and Undersander (2002) since NDF intakes in a low-quality forage system, such as the forage used in our experiments, are higher than 1.2 kg of NDF/100 kg of BW.

The relationship of various independent variables to forage DMI are characterized in the regression equations presented in Tables 6 and 7 for Exp. 2 and 3, respectively. Initial regression analysis indicated minimal improvement in R^2 when $BW^{0.75}$ was used in our models compared with BW; therefore, BW was used for all regressions. Each kilogram increase in milk yield was associated with a 0.33 (Table 6) and 0.37 kg (Table 7) increase in forage DMI for early and late lactation, respectively. These coefficients compare to a 0.2 kg increase in DMI/kg of milk yield used in NRC (1996). During early lactation, BW was the best single variable for predicting forage DMI ($R^2 = 0.68$; Table 6). However, during late lactation, milk yield was the best single predictor ($R^2 = 0.64$; Table 7). During both stages of lactation, the best two variable equation incorporated milk yield and BW with $R^2 = 0.82$ for early and $R^2 = 0.73$ for late lactation. Anderson et al. (1983) reported prediction equations for TDN intake that included BW, weight change, and milk yield ($R^2 = 0.77$). They reported little benefit by incorporating BW^x (where x = various exponents to express metabolic BW) compared with BW. In contrast, Hatfield et al. (1989) found $BW^{0.75}$ better correlated with DMI than BW. Previous research and the results of our analysis indicate that measures of BW and milk yield can explain significant portions of the variation in DMI during lactation in beef cows. The challenge with utilizing milk yield in models predicting intake is that milk yield is not directly measured in beef cows. Fox et al. (1988) estimated milk yield using mature BW of the cows and estimated BW of the male calves at a standard age. However, further development of an accurate estimator of milk yield in beef cows is essential before accurate adjustments for

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Table 7. Sources of variation for forage dry matter intake (kg/d) of Brangus cows during late lactation

Intercept	Milk[a]	$Milk^2$	BW[b]	BCS[c]	Parity[d]	R^2	C_p
Single variable							
8.455*	0.3731*	—	—	—	—	0.46	38.85
4.478*	1.612*	0.0173*	—	—	—	0.64	21.26
2.736	—	—	0.0163*	—	—	0.45	39.27
6.662*	—	—	—	1.002	—	0.08	78.89
10.12*	—	—	—	—	1.704*	0.35	50.71
Two variable							
1.234	1.353*	–0.0152*	0.0088*	—	—	0.73	13.28
0.0452	1.430*	–0.0143*	—	1.142*	—	0.74	12.29
4.439*	1.624*	–0.0174*	—	—	–0.0362	0.64	23.25
2.431	—	—	0.0160*	0.1053	—	0.45	41.18
4.255	—	—	0.0127*	—	0.5762	0.47	39.35
7.283*	—	—	—	0.6707	1.606*	0.38	48.74
Three variable							
2.111	0.3296*	—	0.0140*	—	–0.8550	0.62	25.48
3.770	—	—	0.119*	0.2096	0.6229	0.47	41.02
1.188	0.4781*	—	—	1.576*	–0.4397	0.63	24.29
–0.494	1.332*	–0.0677*	0.0053	0.7762	—	0.76	11.78
–2.196	1.660*	0.0844*	0.0141*	—	–1.404*	0.79	9.09
–1.917	1.660*	–0.0762*	—	1.410*	–0.8349	0.76	11.49
–1.326	0.4502*	—	0.0097*	1.146*	–1.124	0.69	19.89
Four variable							
–4.759*	1.675*	–0.0791*	0.0105*	0.9460*	–1.591*	0.83	6.00

[a]Milk yield, kg/d.
[b]Body weight, kg.
[c]Body condition score, scale 1 to 9.
[d]Parity class where multiparous = 1, and primiparous = 0.
*Significant in model at $P < 0.10$.

milk yield can be incorporated into models estimating intake.

Efficiency of conversion of dietary energy to milk production was expressed as the ratio of milk energy (Mcal of NE_m/100 kg of BW) to energy available for production (Mcal of NE_m/ 100 kg of BW). All NE calculations were estimated from energy-partitioning equations reported by the NRC (1996). Since milk composition was not determined, mean compositional values from the NRC (1996) were used in the calculations to estimate milk energy. Therefore, it was assumed that there was no difference in milk composition due to parity or stage of production. Multiparous cows were over 40% more efficient than primiparous cows during early and late lactation (Tables 4 and 5). These differences could be attributed to several factors, including energy utilization for growth in primiparous cows and/or potential differences in mobilization of body fat, milk composition, and/or maintenance energy requirements. No effect of sire MEPD was noted for either stage of lactation. Marshall et al. (1976) evaluated weaning data from individually fed 2-, 3-, and 4-yr-old Angus, Charolais, and reciprocal cross cows and calves. These researchers expressed efficiency as the ratio of total TDN intake of the cow-calf unit to the weaning weight of the calf. Those females that produced more milk had heavier calves at weaning and were more efficient in converting TDN intake to kilograms of calf BW. In contrast, other researchers have demonstrated that cows that have lower genetic potential for milk production are more efficient, both biologically (Montano-Bermudez and Nielsen, 1990) and economically (van Oijen, et al., 1993).

Beef cows' nutritional requirements peak during early lactation (NRC, 1996). During lactation, the maintenance requirements of cows are estimated to be about 20% higher than nonlactating cows (NRC, 1996). Ferrell and Jenkins (1985) suggested that maintenance energy requirements are positively associated with genetic potential for production. Furthermore, Montano-Bermudez et al. (1990) determined that crossbred cows with high and moderate genetic potential for milk production required 12% more energy per unit of metabolic weight than cows with low genetic potential for milk production to maintain BW. Thus, the increased forage intake because of increased milk production observed during early lactation may be a response to increased maintenance energy requirements in addition to increased productive energy requirements of the beef cow.

Stage of Production. Weather effects could not be separated from stage of production and therefore are confounded with stage of production. All data are expressed relative to BW (Table 8) to eliminate the effect of parity class since these differences were not significant when analyzed for each individual experiment. Body condition score was influenced by stage of production (P =

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Table 8. Least squares means for body condition, milk yield, and intake of Brangus cows consuming low-quality hay over three stages of production

Variable	Stage of production[a] –50 d	62 d	163 d	SEM	P value[b]
n	15	15	15	—	—
BCS[c]	4.7[x]	4.5[y]	4.3[y]	0.11	0.06
Milk yield, kg/100 kg of BW	—	1.79[x]	1.40[y]	0.11	<0.01
Supplement DMI, kg/100 kg of BW	0.21[x]	0.38[y]	0.37[y]	0.01	<0.0001
Forage DMI, kg/100 kg of BW	1.75[x]	2.51[y]	2.12[z]	0.05	<0.0001
Apparent diet OM digestibility, %	56.8[x]	53.7[y]	57.3[x]	0.01	0.01
Mcal of NE_m in milk/Mcal of NE_m available for production[d]	—	1.42	1.59	0.23	0.35

[a]Expressed in average days relative to parturition (parturition = d 0).
[b]P-value for differences due to stage of production effect in the model.
[c]Body condition score, scale 1 to 9.
[d]Mcal of NE_m used for milk was estimated using average milk energy concentration (0.72 Mcal of NE_m/kg of milk) in beef cows from NRC, 1996. Mcal of NE_m available for production was estimated by subtracting maintenance requirements (NRC, 1996) from daily NE_m intake. Daily NE_m intake was estimated from DMI and apparent digestibility data.
[x,y,z]Within a row, means that do not have a common superscript letter differ ($P < 0.10$).

0.06). Body condition was greatest during late gestation and tended to decrease as lactation progressed.

Forage consumption was 44 and 22% greater during early and late lactation compared with late gestation ($P < 0.01$). As cows progressed from early to late lactation, DMI decreased by approximately 18%. Vanzant et al. (1991) reported a 20% increase in forage OM intake of primiparous cows at d 26 of lactation compared with late gestation. Other researchers have demonstrated that during early lactation, cows consume 13 to 50% more feed compared witho late gestation (Ovenell et al., 1991; Stanley et al., 1993; Marston and Lusby, 1995).

Implications

Under the conditions of these experiments, selecting cows for increased milk production within a breed did not alter forage intake during late gestation. However, forage intake was sensitive to genetic potential for milk production during lactation, even when low-quality forage was the primary feed resource. When modeling dry matter intake by lactating beef cows, the adjustment for milk yield may need to be increased compared with the one currently being used by NRC (1996). Dry matter intake was similar between multi- and primiparous cows when intake was expressed relative to body weight. Therefore, separate prediction equations should not be necessary for different parity classes. Finally, models to estimate forage intake by beef cows should incorporate more sensitive adjustments to account for the dramatic increase in intake that occurs after parturition. An adjustment for stage of lactation, beyond milk yield, does not seem to be necessary.

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